Sources of Planetary Rotation: Mapping Planetesimals' Contributions to Angular Momentum

R. Greenberg, M. Fischer (U. Arizona), G.B. Valsecchi, A. Carusi (CNR/IAS Planetologia, Roma)

A systematic study of motion backward and forward in time, starting from a uniform distribution of bodies entering a growing planet's Hill sphere, yields a mapping of the contribution to the planet's rotation from planetesimals as a function of their source in heliocentric orbital element space. The method was suggested by numerical studies by Tanikawa et al. (1991, Icarus 94, 112) of motion of such a population of planetesimals as they approach the planet from the Hill sphere. We found that contrary to the interpretation of Tanikawa et al., such motion follows two-body behavior in most cases of importance, with correspondingly predictable contributions to rotation. We also numerically integrated the motion backwards in time to map these planetesimals back to their source heliocentric orbits. This mapping allows determination of the contribution from any assumed distribution of heliocentric planetesimal orbits. For example, for the initial populations assumed by Lissauer and Kary (1991, Icarus 94, 126) and by Dones and Tremaine (1993, Icarus 103, 67) in their Monte-Carlo studies, our mapping can systematically reproduce their results for contributions to rotational angular momentum. Our mapping confirms Lissauer and Kary's discovery that planetesimals at the edges of a growing planet's feeding zone make the greatest contribution. With our method of calculation, such contributions to planetary rotation can be readily interpreted (taking the point-of-view introduced by Tanikawa et al.) in terms of the arrival geometries at the planet's Hill sphere and the subsequent two- body motion inside the Hill sphere leading to impact. Prograde rotation is strongly favored if a planet grows in a relatively quiescent population of planetesimals with accretion nibbling at the edges of its feeding zone. However, if the impacting population were dominated by large bodies with high relative velocity, the direction and magnitude of rotation would be random.

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Paper presented by Richard Greenberg
Lunar and Planetary Lab
University of Arizona

Tucson AZ 85721 USA
Phone: 520-621-6940
Fax: 520-621-5133
Email: greenberg@lpl.arizona.edu

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